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Technical Report

SURVEY: AUTOMATED FIELD OPERATIONS AND SERVICES (AFOS)

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TECHNICAL REPORT
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SURVEY: AUTOMATED FIELD OPERATIONS AND SERVICES (AFOS)

Prepared For

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MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

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APPROVED:

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INTRODUCTION

The National Weather Service (NWS) is currently implementing a program for improving operations through automation of routine functions, improved communications capability, and improved management and presentation of data. The program, designated as Automation of Field Operations and Services (AFOS), uses high-speed (currently 2,400 baud) data circuits, minicomputers, and dynamic display devices to rapidly collect, disseminate, and present data to forecasters and users on both a broadcast and a request basis. The initial system will be configured to serve facilities within the continental United States, Alaska, Hawaii, and Puerto Rico, with eventual expansion to provide international capability.

This introduction discusses AFOS users, functions, and network and site configurations. The numbered sections discuss current and future capability and workload in terms of the 10 data systems elements designated by NASA.

AFOS USERS

The NWS field structure for technical operations is presented in Figure 1. AFOS services each level within this organization, however, the initial implementation services only 201 of the 245 WSOs. In addition, AFOS stations will be located within the National Climatic Center (NCC) and the Satellite Field Service Stations (SFSS) of the National Environmental Satellite Service (NESS), and interfaces will be provided to the FAA Weather Message Switching Center, DoD (AFGWC and Fleet Numerics), the Forestry Service, international organizations, and other NWS programs.

AFOS FUNCTIONS

The AFOS system handles all communications between NWS elements where it is installed; it maintains the station data base, which is

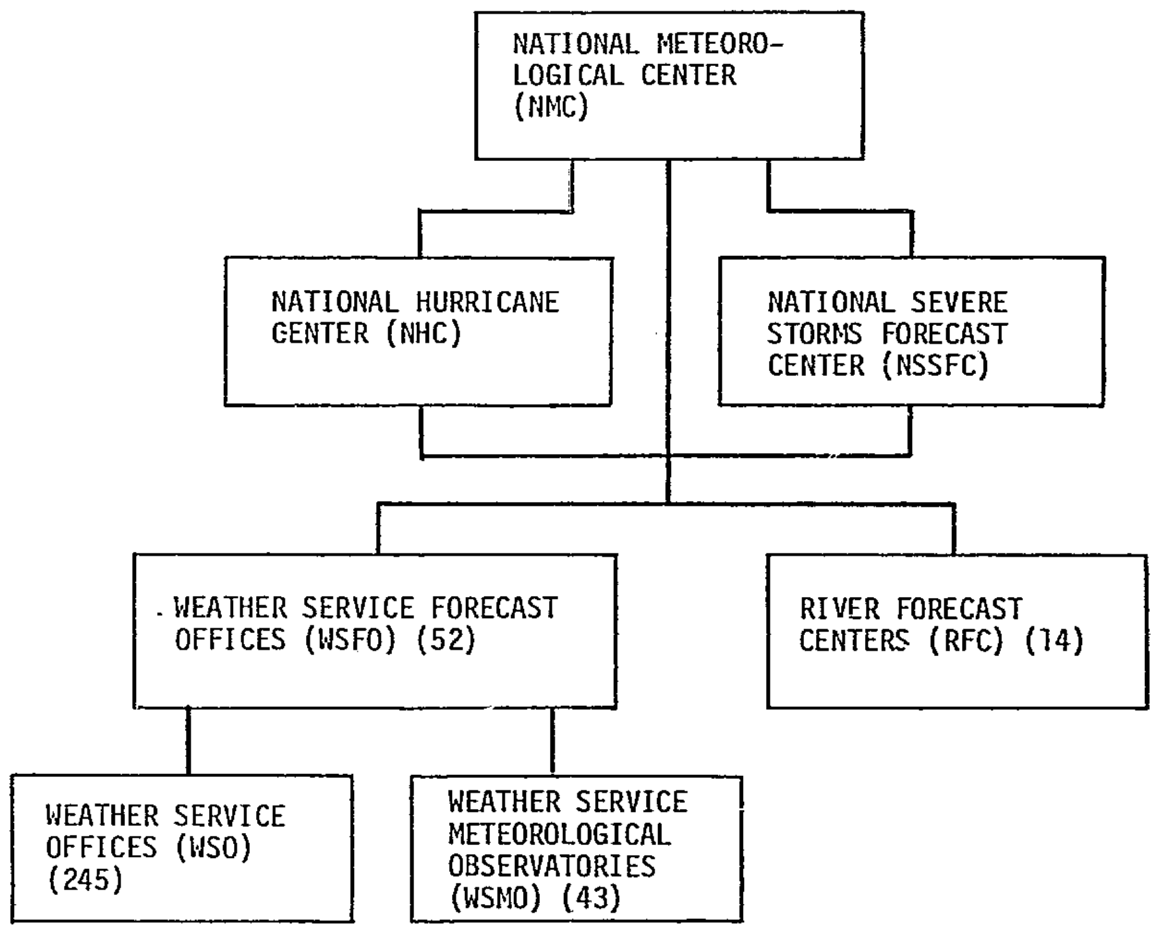

FIGURE 1. NWS FIELD STRUCTURE FOR TECHNICAL OPERATIONS

selectable and variable from site to site; it services the forecasters' data requests; and it drives the alphanumeric and graphic displays within the system. As the program matures, the AFOS is expected to pick up added roles, eventually to include forecasts of selected parameters.

Improved communications is a primary function of the AFOS during its initial stages of development, with emphasis on improvement in warning response time for severe weather and weather-related events. Figure 2 provides a comparison of the relative improvements expected in warning response time for a typical warning message. In absolute time, the preparation and dissemination of a warning message via paper tape and teletype circuits currently consumes between 5 and 15 min. The AFOS will reduce the time to somewhere between 1 and 2 min at the most.

Each AFOS site maintains a data base of information of interest to that station. The contents of any given data base are variable and are selected from a Product Information List (PIL) containing 2,300 products. A site would, for example, retain the inputs for all surrounding sites that have the potential for impacting its weather and/or those sites that may be impacted by the local weather. In addition, each site would likely maintain data bases on other sites where locally originating aircraft either pass through or terminate. One limitation on the data base is that a site within the AFOS network can only access the data base contents at the next higher level in the network hierarchy. Thus, if the Huntsville WSO requires data on weather in the Los Angeles area to support Huntsville originating flights that terminate in Los Angeles, arrangements must be made for the Birmingham WSFO to acquire this information from the PIL and to retain it in the Birmingham WSFO data base for subsequent use by the Huntsville WSO. Once acquired from the WSFO data base, the local WSO has mass storage facilities to store the data until new data are entered.

Another primary function of the AFOS is to service forecasters' requests for both narrative/tabular data and graphic data via the display and hardcopy presentation systems available within each AFOS site.

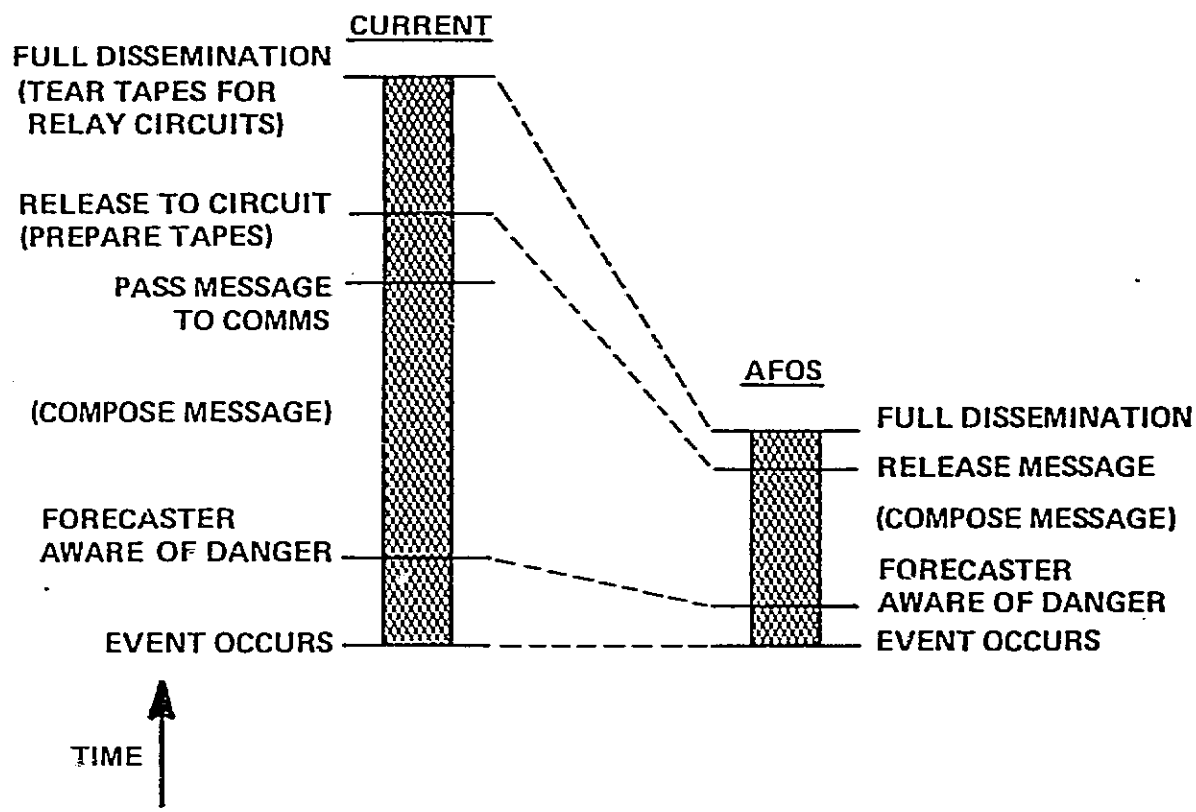

FIGURE 2. EXPECTED IMPROVEMENTS IN WARNING RESPONSE TIME BETWEEN AFOS AND CURRENT APPROACH

Although hardcopy data are available, a primary goal of the AFOS is to significantly reduce the paper (teletype and facsimile) that flows into a WSFO/WSO. This is accomplished in the AFOS through the use of a cathode ray tube (CRT) display system with alphanumeric and graphic display capability. The forecaster may view any data retained within the local data base. In addition, a forecaster may request any data retained at the next higher level in the AFOS hierarchy for viewing when made available.

The functions performed by AFOS will increase as the system matures. A goal is for the system to eventually be used for producing forecasts. However, the plans as to how this will take place have not been approved. It is envisioned that the use for forecast purposes will evolve over a period of time as the forecasters become accustomed to the AFOS.

AFOS CONFIGURATIONS

AFOS configuration includes two aspects: 1) communication system configuration and 2) equipment configuration within the various user facilities. An overview of these configurations at the WSFO and WSO levels is presented here. Details at these levels and at the national level are provided in subsequent sections.

One of the most important considerations in the design and development of the AFOS was modularity. The system is configured at each station or node so that additional minicomputer and storage capacity, terminal devices (on- or off-site), communications lines and associated modems, hardcopy and dynamic displays, and other peripheral equipment can be added on a modular basis. Thus, the capability to increase AFOS system capacity at any node in the network is virtually unlimited from a technical viewpoint.

The AFOS National Distribution Circuit (NDC) configuration is presented in Figure 3. Each node in the network operates in a store and forward mode for all data on the circuit. The node may either extract

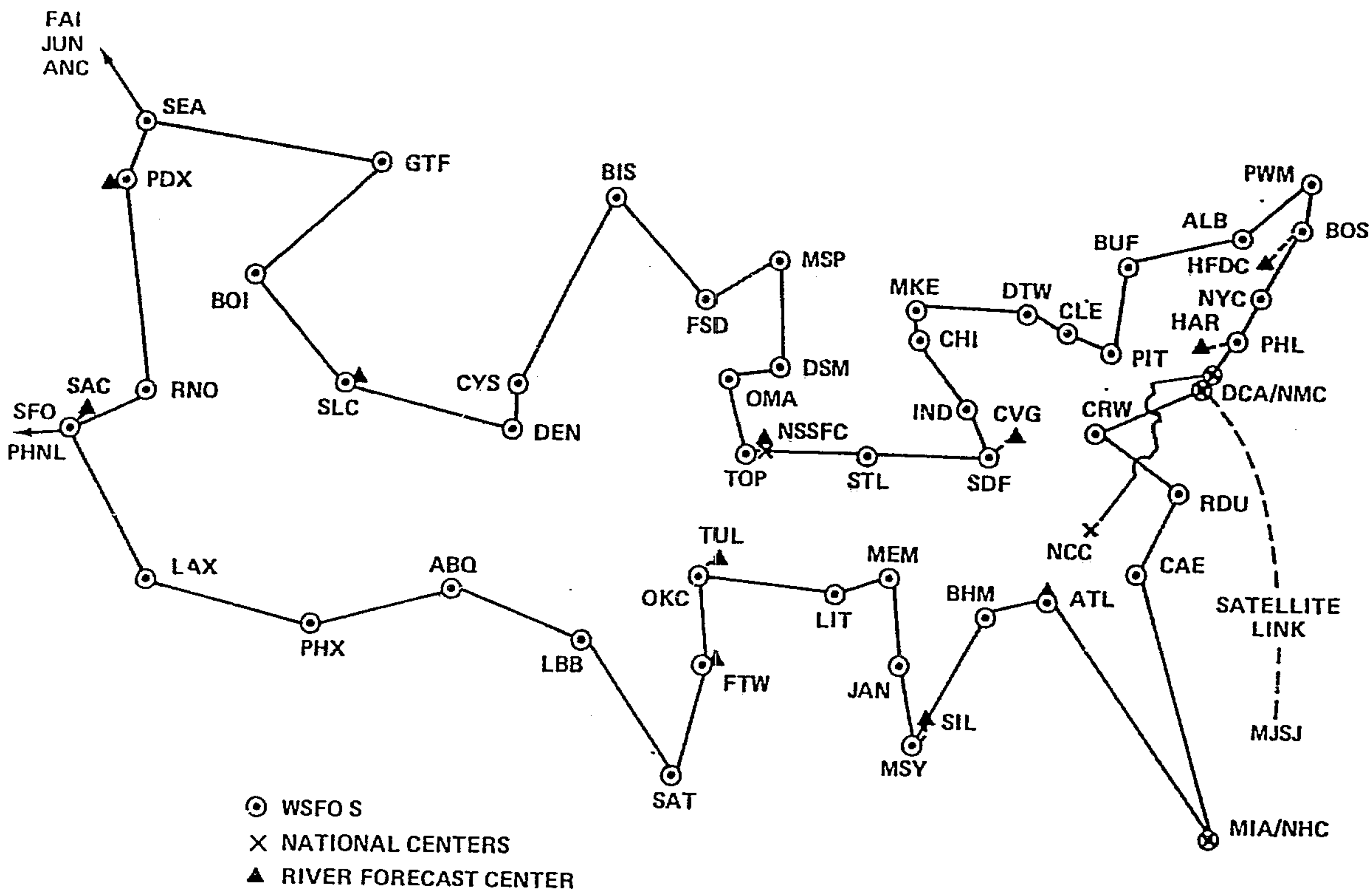

FIGURE 3. AFOS NATIONAL DISTRIBUTION CIRCUIT (NDC) CONFIGURATION

data as it passes through the node or it may request data from the central data base. In addition, the node may enter data into the data stream. Data entered via a node travels in both directions around the circuit until it arrives at a node where it has already been received from the opposite direction. When this happens, the message is removed from the circuit.

Each node on the NDC connects to a State Distribution Circuit (SDC), which distributes the data to the WSOs within its jurisdiction as illustrated in Figure 4. (Generally, the WSOs tied to a WSFO are constrained to those WSOs within the same state boundaries, but this is not always the case.) In addition, WSFOs and WSOs may provide connection to River Forecast Centers, Weather Service Meteorological Observatories, and others as illustrated in Figure 5. The level of interaction with AFOS decreases as the node gets farther from the NDC. For example, a WSO has direct access only to that data retained in the WSFO data base. Indirect access to anything in the Suitland data base is available on a request basis via the WSFO. Also, some groups are only users of data (e.g., radio, TV) and others are only suppliers of data (e.g., observatories). A typical RFC complex and its interface to AFOS are illustrated in Figure 6. Future plans call for interfacing the AFOS to additional NWS elements, such as the radars, but schedules for this expansion are not available.

The nodes that make up the NDC and the SDC are configured according to the responsibilities of the node and the number and types of other elements to which it is interfaced. Figure 7 presents a typical AFOS WSFO configuration, along with its interface to the NDC, other NWS facilities, and users. Figure 8 presents a basic WSO configuration. A particular WSO may have only this basic configuration or it may have more equipment than illustrated if its responsibility is greater than is typical for a WSO. The modularity of this system makes expansion to accommodate added functions relatively easy.

Each of the configurations in Figures 7 and 8 contains a system console. This system console contains the minicomputer (or minicomputers

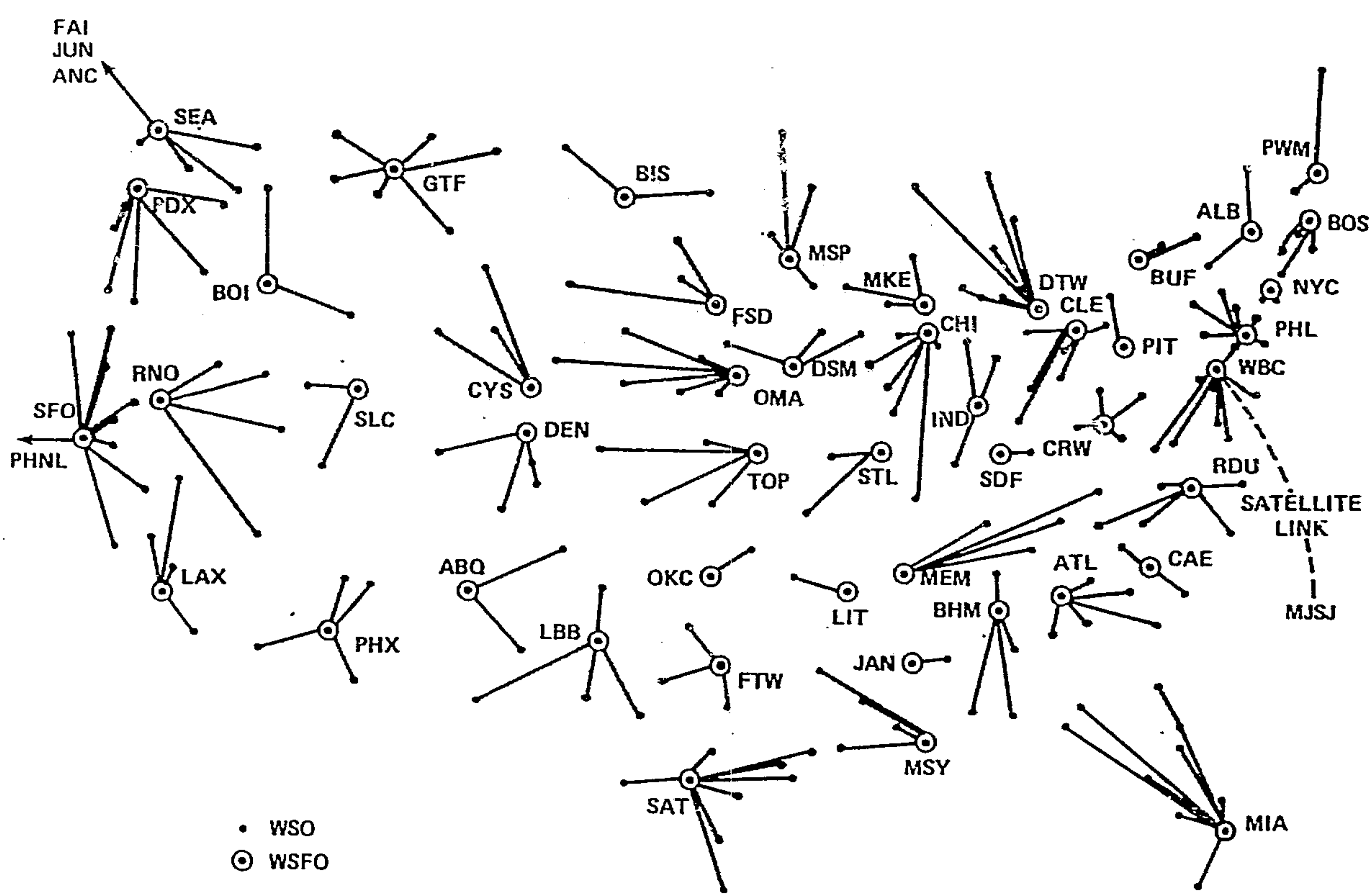

FIGURE 4. AFOS STATE DISTRIBUTION CIRCUITS (SDC)

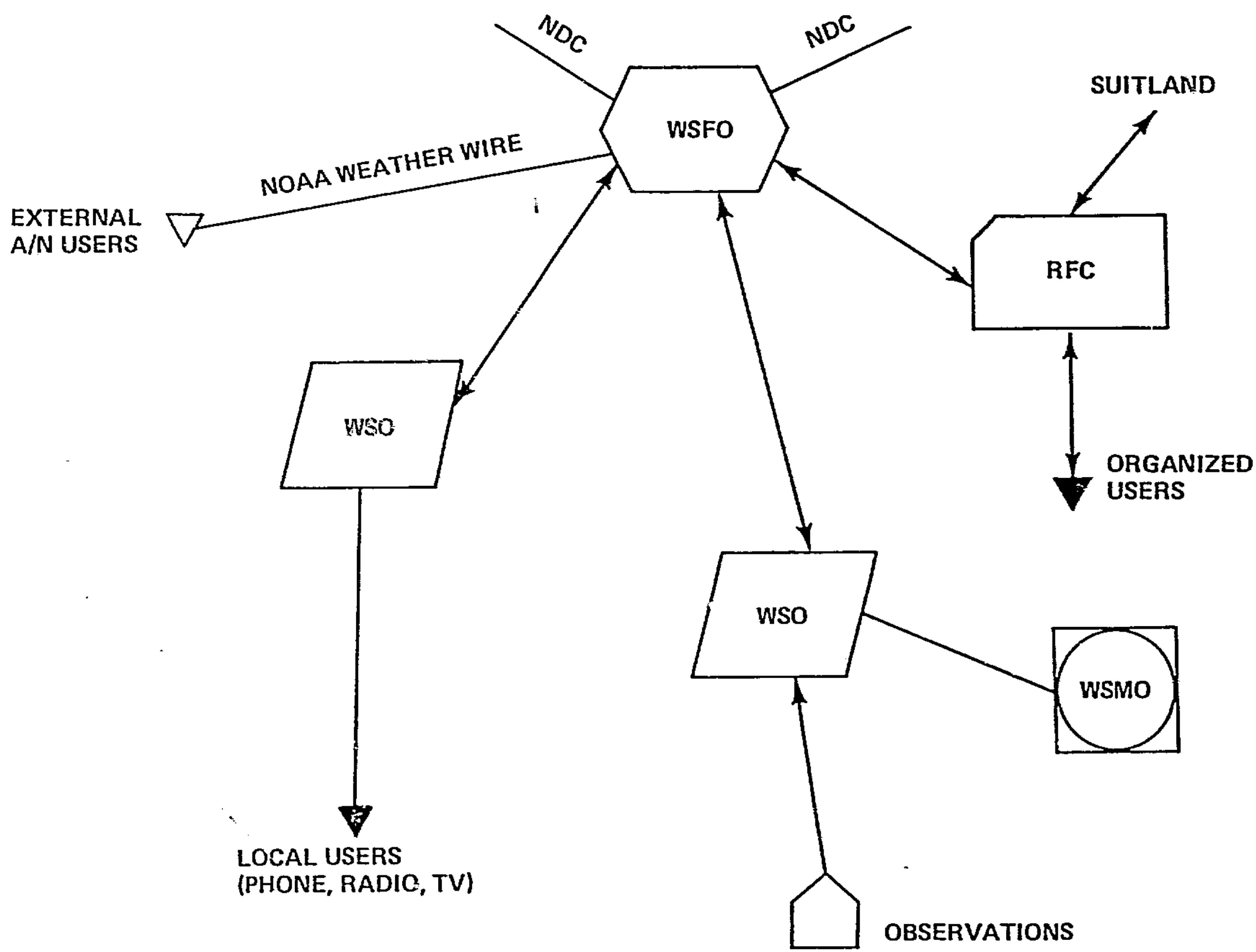

FIGURE 5. WSFO-AREA COMMUNICATIONS ASSOCIATED WITH AFOS

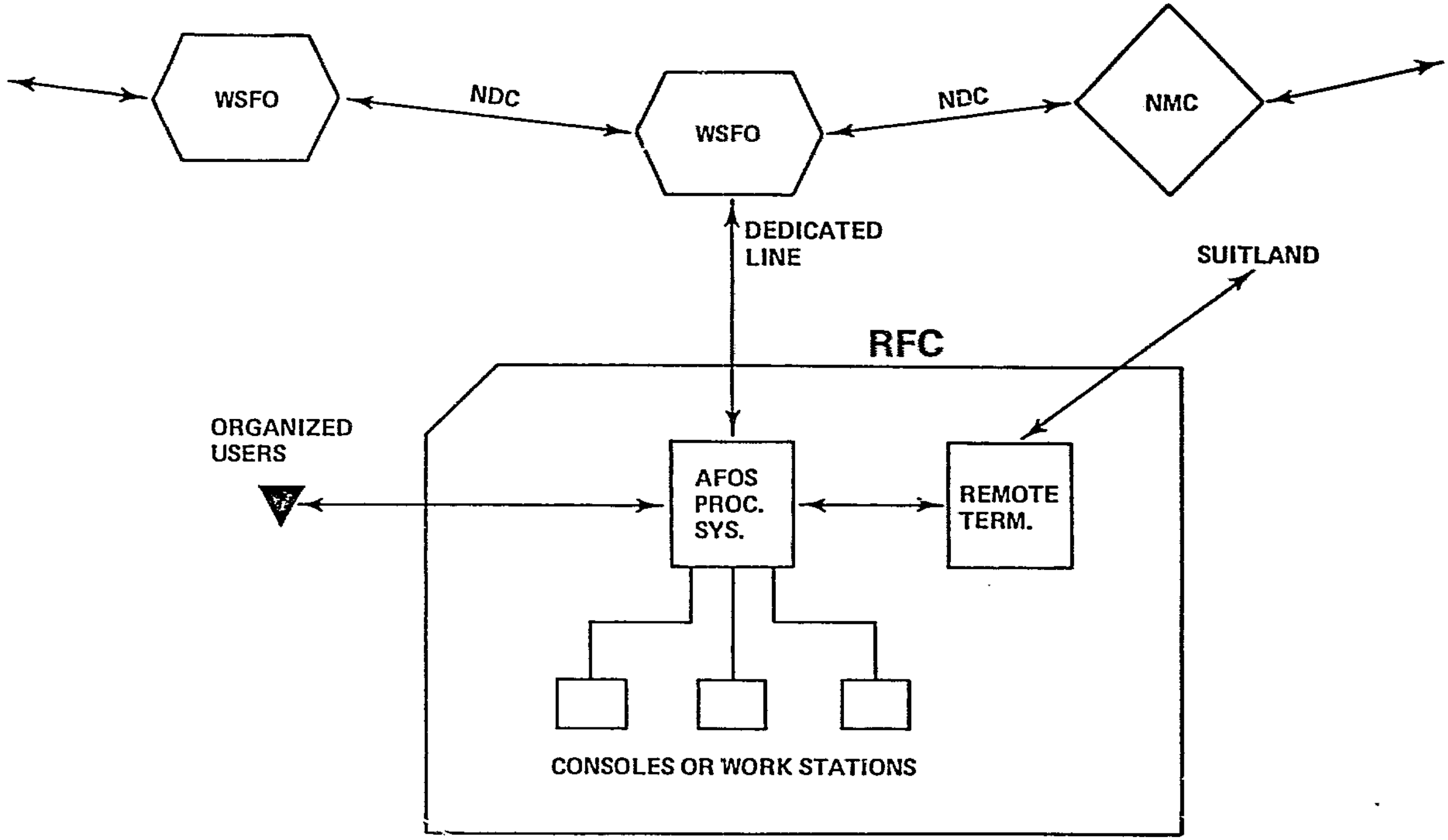

FIGURE 6. TYPICAL RFC COMPLEX INTERFACE TO AFOS

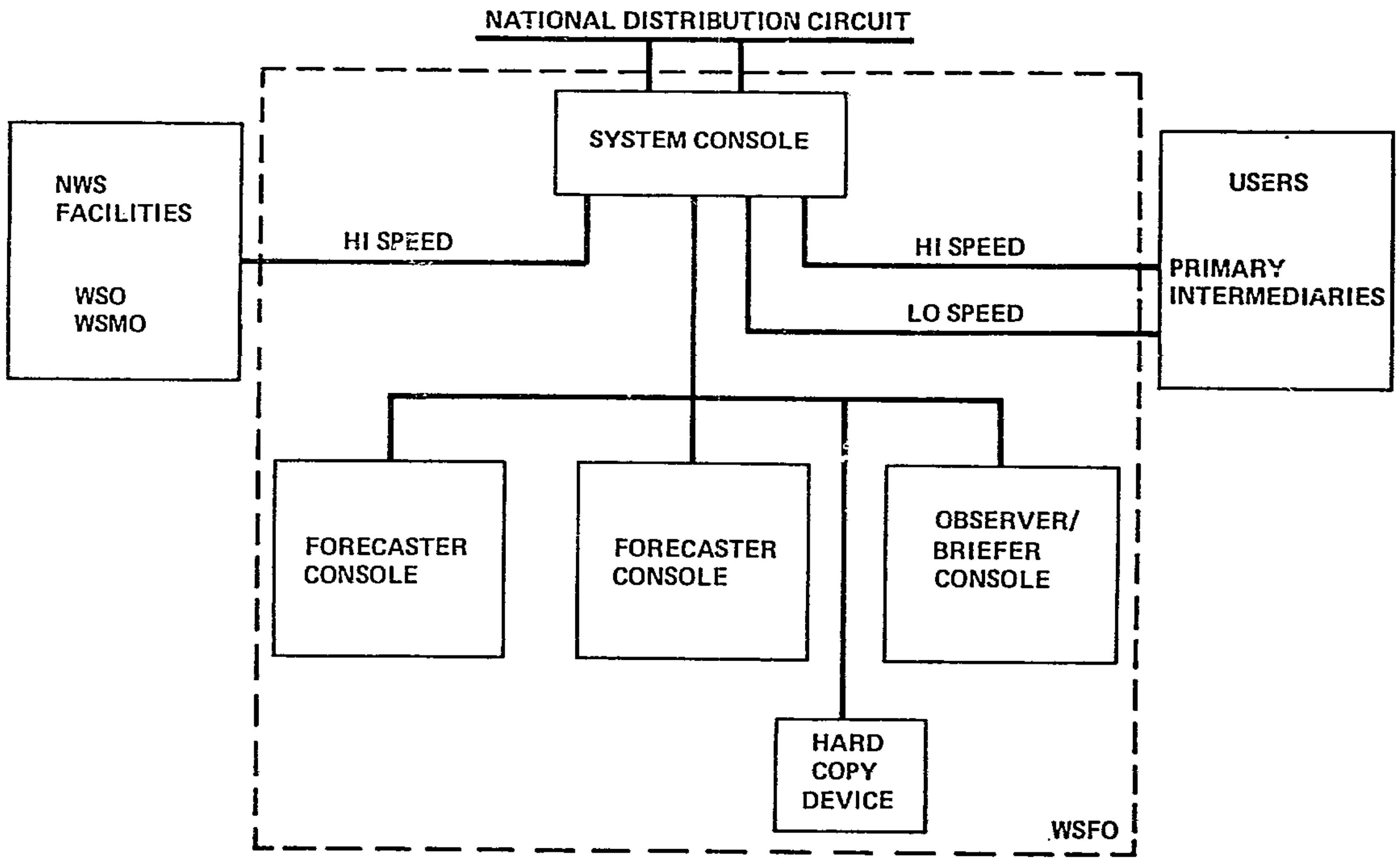

FIGURE 7. TYPICAL AFOS WSFO CONFIGURATION

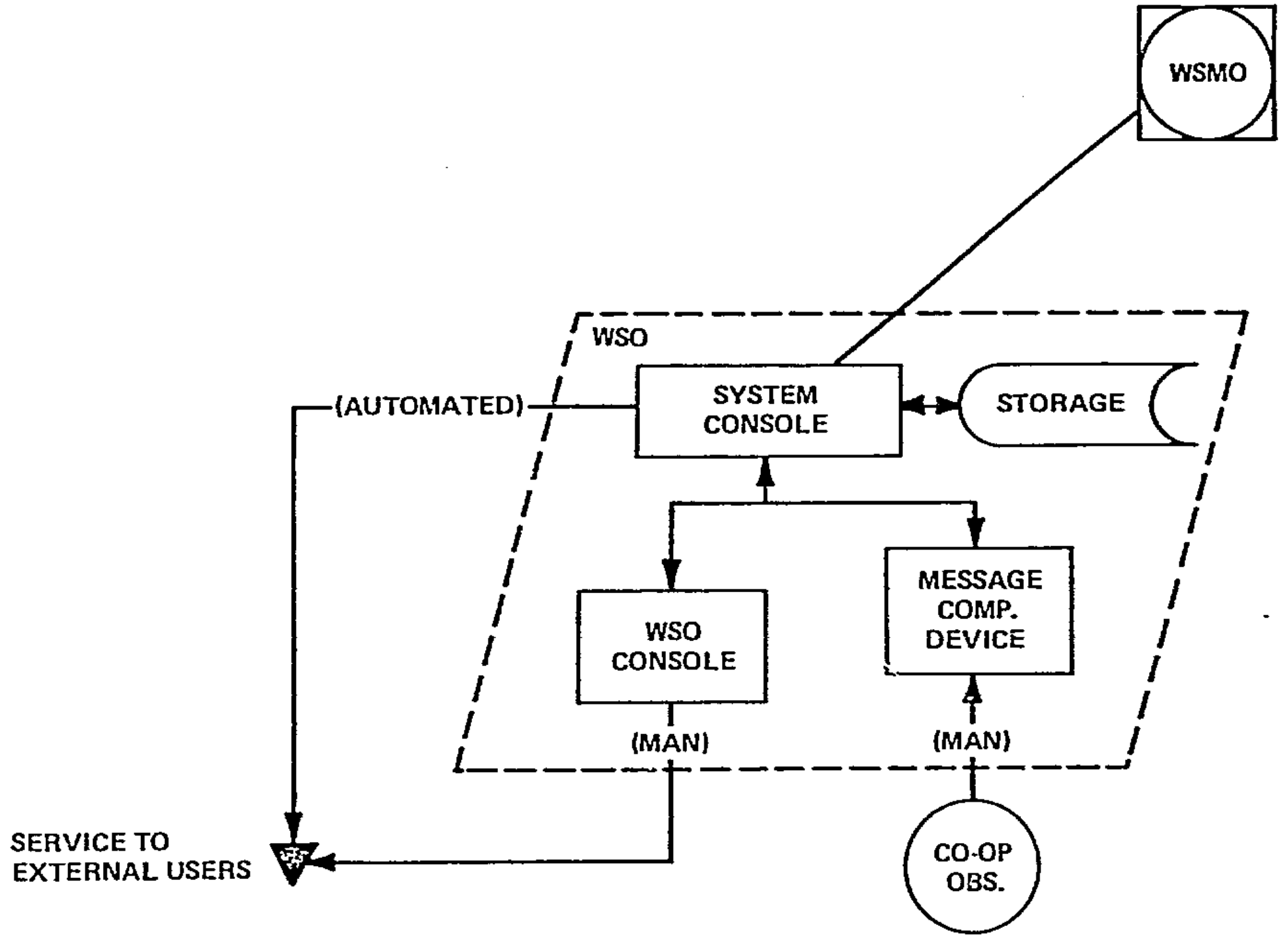

FIGURE 8. BASIC AFOS WSO CONFIGURATION

depending on the type station), the communications interfaces, the clock, the mass memories, and an alphanumeric display with a keyboard. The system console controls all data flow and processing within the station and is under the control of a hardware/software communications specialist. The alphanumeric display enables this specialist to monitor and control the interface to the NDC and SDC, and in addition it may be used as the I/O for interacting with and diagnosing the computers and the software within the station.

The forecasters interact with the data base via the forecaster console. A forecaster console may contain anywhere from two to four graphic CRT devices that enable the forecaster to view either alphanumeric, graphic, or image (future) data within the data base on demand. The data viewed may be either in normal or zoom mode (i.e., a selected area of the picture may be offset and enlarged to cover the entire screen). Other features include shades of gray, line texturing, and special symbols that enable meteorologists to communicate in coded formats that reduce clutter on maps, pictures, etc.

The forecasters console also contains an alphanumeric terminal with a keyboard for message composition, as well as a special keyboard for retrieving data from the data base. Messages composed at the station are coded with a priority that enables them to be integrated with the other data on the network in accordance with need and data circuit loading.

1. SPACE DATA GENERATOR ELEMENTS

Not Applicable

2. SPACE DATA PROCESSING ELEMENTS

Not Applicable

3. SPACE DATA STORAGE ELEMENTS

Not Applicable

4. SPACE DATA HANDLING ELEMENTS

Not Applicable

5. SPACE TO GROUND COMMUNICATION ELEMENTS

Not Applicable

6. PREPROCESSING ELEMENTS

Not Applicable

7. PROCESSING ELEMENTS

AFOS processing elements are presented in this section in terms of National Centers, WSFOs, WSOs, WSMOs, and River Forecast Centers. National centers include the NMC, the NSSFC, the NHC, the NCC, and the SMCC.

7.1 NATIONAL CENTER PROCESSING ELEMENTS

7.1.1 System Monitoring and Coordination Center (SMCC) Processing Elements

The SMCC is the monitoring and control center for the total AFOS network. It is responsible for assessing the status of the system, maintenance of system software, and evaluation of AFOS operations. It also maintains a data base of up to 30 days' meteorological data. In addition, it provides the capability for a node to recover from failure on the SDC by allowing that node to access the data base when normal operations are resumed to replenish its local data base. The SMCC is connected to the IBM 360/40 system that handles communications for the NMC via computer to computer interface.

The data processing elements within the SMCC are composed of the following hardware and software elements:

- SMCC Data Processing Hardware
  - ▲ Data General Eclipse S/230 Computer (2)
    - 96K bytes memory
    - Used as communications computer and as backup system
  - ▲ Data General Eclipse S/230 Commuter (2)
    - 256K bytes memory
    - Used for processing and accessing data base and backup system
  - ▲ Data General 4234 Disk (10 M bytes)

- ▲ Large Capacity disk (2)
  - Used to maintain 30-day data base of all information
- ▲ Floppy Disk

- SMCC Software
  - ▲ Data General MRDOS Operating System
  - ▲ Communications Software (see Section 9)
  - ▲ Data Base Management Software (see Section 8)
  - ▲ Graphics Software

The SMCC hardware is basically the same as a standard AFOS station with the exception of two large capacity disk drives to maintain data for a 30-day period, and added processors for reliability and workload.

7.1.2 AFOS Processing Elements Within the NMC

The NMC is a unique center within the NWS by the fact that it generates forecasts over such a large area. As a result, the NMC accepts inputs from and generates outputs to all AFOS sites. The AFOS station within the NMC is connected to the NMC data base as illustrated in Figure 7-1. The AFOS data processing elements within the NMC consist of the following hardware and software items:

- AFOS Data Processing Hardware
  - ▲ Data General Eclipse S/230 Computer
    - 96K bytes memory
    - Used as communications computer
  - ▲ Data General Eclipse S/230 Computer
    - 256K bytes memory
    - Used for processing and accessing data base
  - ▲ Data General 4234 Disk (10 M bytes)
  - ▲ Floppy Disk

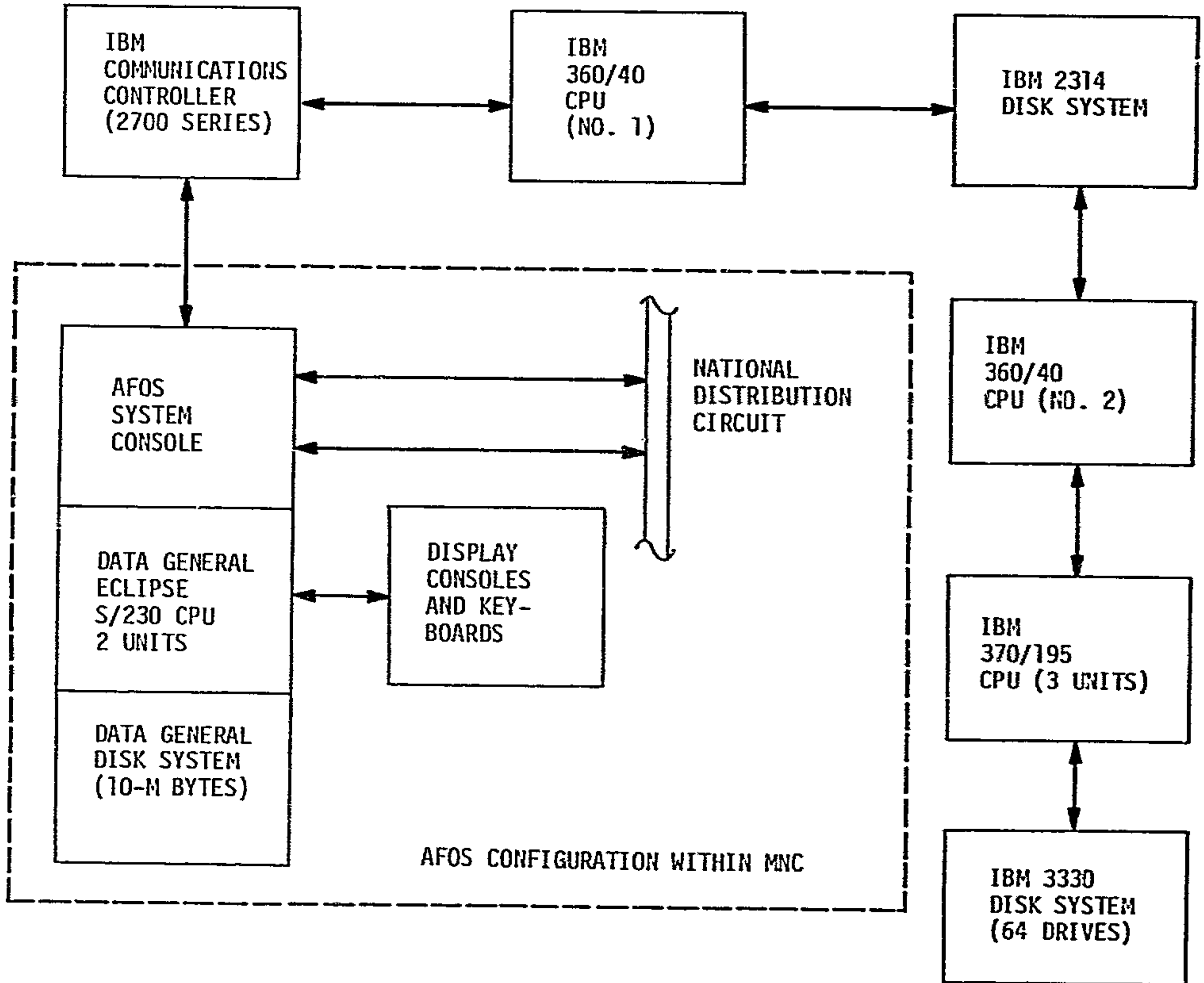

FIGURE 7-1. AFOS INTERFACE TO NMC COMPUTERS

- AFOS Software
  - Data General MRDOS Operating System
  - Communications Software (see Section 9)
  - Data Base Management Software (see Section 8)
- Graphics Software.

The hardware elements within the AFOS are modular. Therefore, additional CPUs, memory, and mass storage can be added to the system at any site as required. The volume of data being processed and displayed at the NMC could necessitate the addition of more processing capability than presently planned.

7.1.3 AFOS Processing Elements Within Other National Centers and WSFOs

The planned processing capability within other national centers (NSSFC, NHC, NCC, AFGWC, and SRSSs) is the same as presented in paragraph 7.1.2 for the NMC with two exceptions: 1) all other centers interface to the NMC data base via the NDC and 2) the NSSFC will have three Data General Eclipse S/230 computers. The third unit will be used by the Techniques Development Unit of the NSSFC and it is not firm at this time as to whether this additional unit will function in an on-line or an off-line mode. The interface to other processing elements within the national centers will vary from one center to another, depending on what other capability exists within a center. The configuration within the WSFOs is shown in Figure 7-2. In general, it is expected that the referenced hardware configuration will replace any existing processing capabilities within a WSFO. The communications and display elements that are presented in this figure are discussed in Sections 9 and 10, respectively.

The above referenced configuration uses the same basic software as is used in the NMC configuration.

7.1.4 AFOS Processing Elements Within WSOs

A standard WSO processing configuration consists of one Eclipse S/230 processor with 128K bytes main memory, a 10 M byte disk

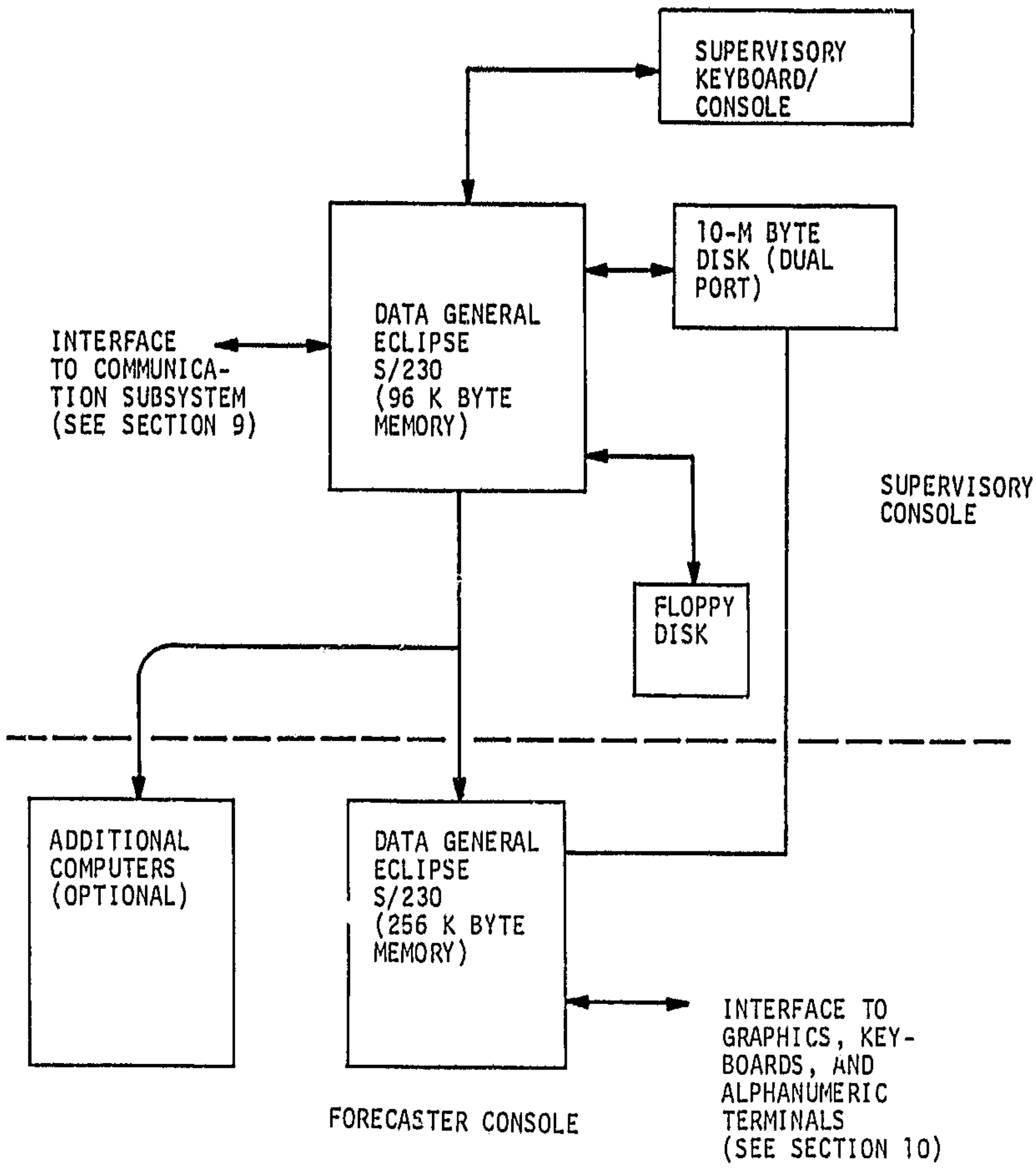

FIGURE 7-2. WSFO DATA PROCESSING ELEMENT CONFIGURATION

for on-line memory, and a floppy disk for archival storage as illustrated in Figure 7-3. The Eclipse CPU performs all communications, data base management, and display functions. Certain WSOs are configured to communicate with River Forecast Center, WSMOs, and automated observatories. Others communicate only with the WSFO. In the future, some WSOs will be interfaced to automated radar systems. Thus, the software will vary from one site to the next. The WSO uses the same operating system and the same basic display software as the WSFOs.

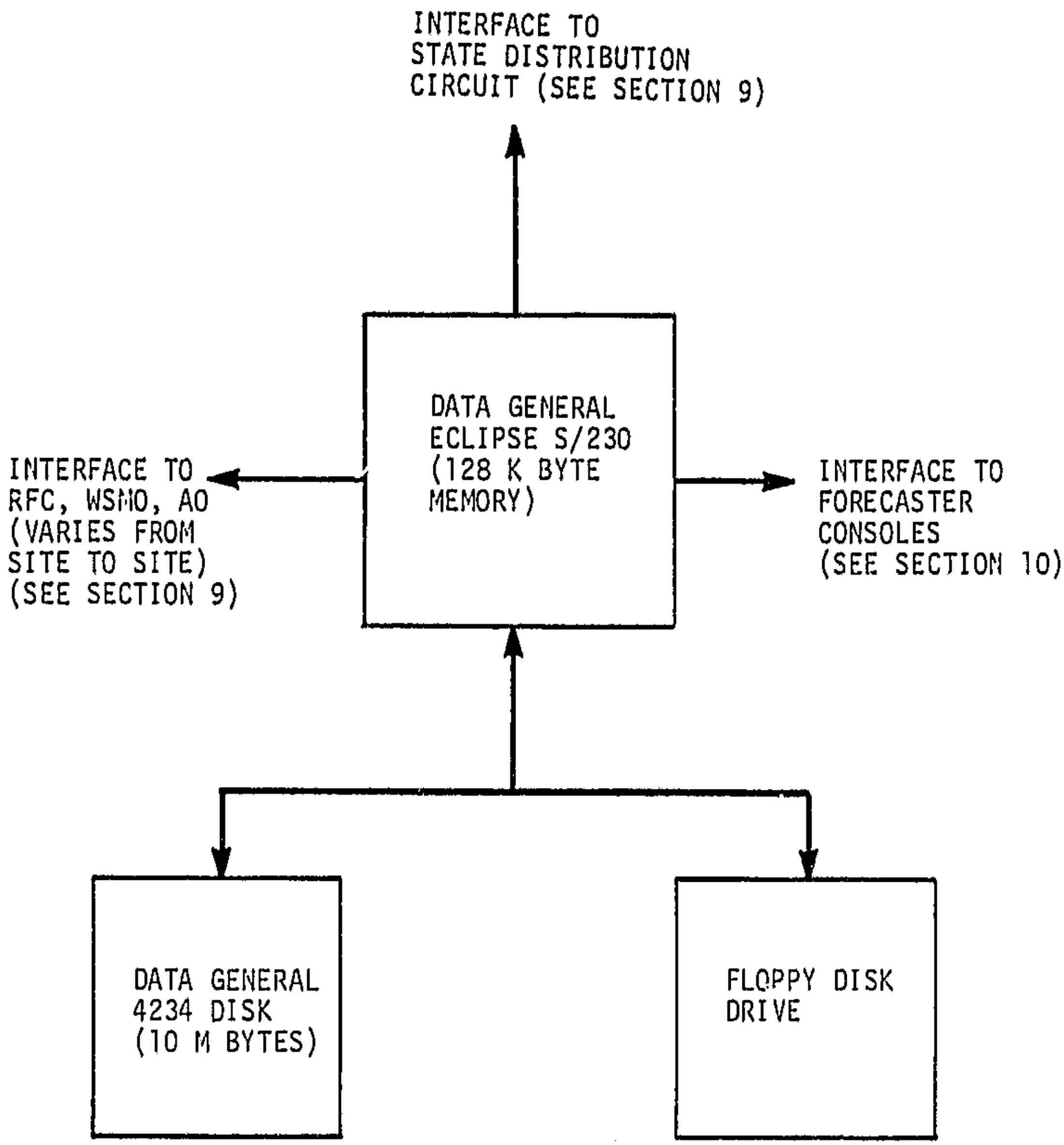

FIGURE 7-3. TYPICAL WSO DATA PROCESSING SYSTEM CONFIGURATION

8. AFOS DATA BASE SYSTEM ELEMENTS

Each AFOS site maintains a data base containing data items that are pertinent to that site. The SMCC maintains an on-line data base for all data items that are current within the AFOS network, plus limited historical data. (Historical data are retained on disks at the SMCC for up to 30 days, at which time the data are sent to the NCC in Ashville, North Carolina, for permanent archival.)

The data that are stored in data bases at the different sites are determined by the site. Each site has access to 2,300 items on the Product Information List (PIL) and may request any of these items. When that item passes a node, the item is automatically selected from the list and placed within the data base. The only limitation in the selection is that the next higher level in the AFOS hierarchy must have selected the item for retention within its data base. (For example, before a WSO can select an item from the PIL, the parent WSFO must have selected that item for retention within its data base.)

The software for managing the data base is currently being developed by the AFOS contractor as part of the overall AFOS software. The data are placed in the disk file using the pushdown technique whereby the last data in are placed on top of the stack. If the file is set up to retain X records, the X + first record is popped out when a new record is placed in the file. The system supports variable length records and is independent of the data type or format.

Data may be called from the file in any of a number of pre-programmed formats. The extent to which a site can tailor the data to its individual needs independent of certain preprogrammed formats has not been decided at this time.

9. AFOS INFORMATION DISTRIBUTION ELEMENTS

This distribution of weather data is one of the most important functions of the AFOS system. Data distribution elements are discussed in terms of the network characteristics and the communication hardware at each node in the network.

9.1 AFOS NETWORK CHARACTERISTICS

The AFOS network consists of the National Distribution Circuit (depicted in Figure 3 of the Introduction), the State Distribution Circuits (Figure 4 of the Introduction), and area communications (illustrated in Figure 5 of the Introduction). Area networks vary widely from one facility to another.

Communications between network nodes take place via 2,400-baud, synchronous, full duplex land lines. Each node in the NDC operates in a store and forward mode using 256 character blocks at the 2,400-baud rate. Both LRC and CRC codes are used for error correction. All communications on the NDC and SDC are synchronous using ADCCP protocol. Lower data rate transmissions to users, such as the NOAA Weather-wire users, are asynchronous.

Although the System Monitoring and Control Center (SMCC) is the control center for the network, it does not govern the flow of messages onto the network. Any node may input data to the network at any time. Data are entered on the basis of priority, which is monitored and controlled at each node as the message passes through that node. Five levels of priority exist, with warnings taking the highest priority (Priority 1). Within queues, messages are grouped by priority level rather than destination. Thus, a message with Priority 1 is immediately forwarded ahead of all other messages with a lower priority. Messages received with the same priority are serviced on a first-in, first-out basis.

The network handles both alphanumeric and graphic data. Graphic data are coded using one of three graphics codes, which vary according to

the particular data being transmitted. Graphics are transmitted in 256 character blocks, similar to alphanumeric data. A typical graphic presentation ranges from eight to fifteen blocks. The volume is reduced as a result of the background data being stored at each local site.

9.2 AFOS COMMUNICATIONS HARDWARE

The AFOS communications hardware, including the interface to the NDC and SDC, is illustrated in Figure 9-1. The system uses Universal Data System (UDS) 2,400-baud modems to connect to the NDC and the SDC via a Data General Synchronous Line Multiplexer. Line operation is full duplex, and full character buffering is available. Up to 16 lines can be supported by this multiplexer. A Data General Data Control Unit 50 (DCU/50) interfaces the multiplexer to the DG Eclipse S/230. Communications with the multiplexer are via the DCU/50 I/O bus, which is separate from that of the Eclipse. The DCU/50 can be programmed for composite throughputs of up to 48K characters per second over a maximum of 256 synchronous lines. For increased communications loads, several DCU/50s can be connected to the same Eclipse processor.

9.3 AFOS COMMUNICATIONS SOFTWARE

The AFOS communications software consists of programs written specifically for the purpose of handling data transfer on the NDC and SDC. This software is written almost exclusively in DG Eclipse assembly language.

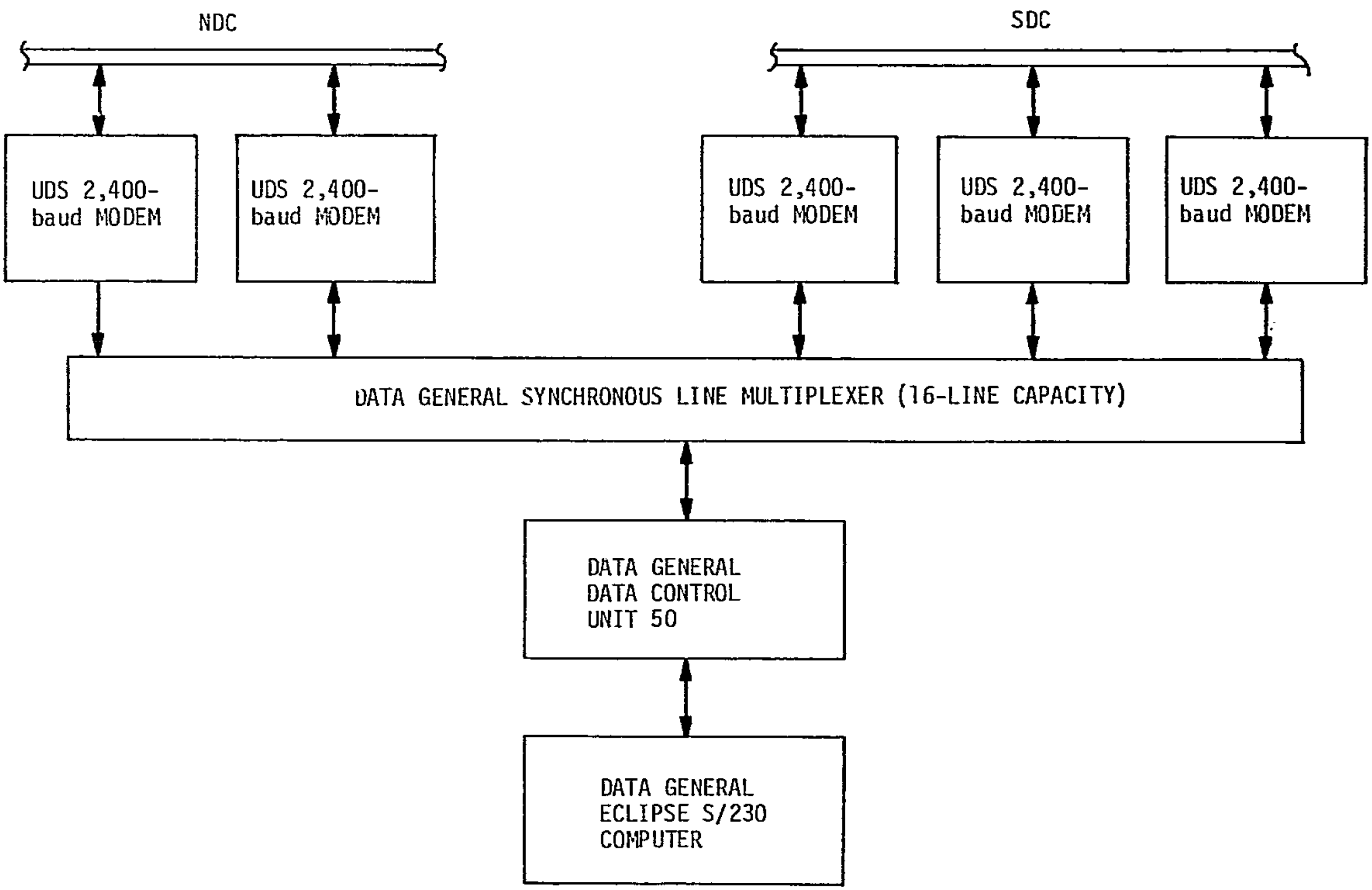

FIGURE 9-1. AFOS COMMUNICATIONS HARDWARE CONFIGURATION

10. INFORMATION PRESENTATION ELEMENTS

Information presentation elements within an AFOS site include the system console (an A/N CRT), the forecasters consoles [graphic CRT(s)], and a hardcopy presentation device that copies directly from either the system or the forecaster's display.

The system console is an alphanumeric CRT device with a keyboard for composing and editing messages and for either system/network control or interrogating the data base. Messages may be composed and edited on the console without interfering with ongoing computer operations until the message is ready for processing.

A typical AFOS site may have anywhere from one to four forecasters consoles, depending on workload. The forecaster's console is a graphic CRT, using a 17-in. Philco Ford display with a data entry and control keyboard. The display has capability for presenting alphanumeric, graphic, and image data. However, the image capability is not currently being implemented. Special features of this display include offset, zoom, shades of gray, and line texturing. These features may be applied to provide an overlay/accumulate features that permit up to three analysis and forecast charts to be sequentially overlayed on the screen without disturbing the image.

A Versatec hardcopy printer is available at each site to reproduce any alphanumeric, graphics, or image data presented on either of the preceding display devices.

11. WORKLOAD AND CAPABILITIES

The AFOS system is still in the development stages. Therefore, the workload on the system is still speculative, at best. NWS and Aeroneutronic Ford have attempted to estimate workload through analysis and simulation of projected activities at the individual nodes (WSFOs, WSOs, national centers, etc.) and the results are presented in subsequent paragraphs.

Based on the network loading analyses performed by NWS and Ford, a typical message placed on the NDC will traverse the network in approximately 1 min. Simulations have projected that the best time around the network is approximately 26 sec. Worst case time for Priority 5 data is considered to be 1 hr. The actual time is, of course, a function of local activity along the path the message must travel. If a path is heavily loaded in one direction, the message may be able to move at a reasonable speed in the other direction. Thus, AFOS implementation personnel do not expect to encounter this worst case situation except in very rare instances.

Network utilization over the 24-hr period is expected to average out to approximately 20%. The utilization will be heavy during certain periods when observation data are being collected and/or forecasts (particularly graphics) are going out. It will also be heavy during severe weather that covers relatively large areas.

As for processing workload, the planned configurations are expected to satisfy all processing requirements at the WSO and WSFO level for the immediate future, including some future forecasting activities. The processing load at the national centers is highly variable, depending on the other processing capabilities that exist at that center.

Capabilities associated with the AFOS have been presented in preceding sections assuming that the entire AFOS network is up and running. One apparent weakness in the AFOS network is the series connection between nodes. The AFOS development and implementation staff is

aware of this weakness and has devised a number of approaches for minimizing the effects of an outage along the network. First, each site along the NDC has two computers. Although one computer is designated as the communications computer, the second computer can assume this duty in the event of a failure on the primary communications computer. The changeover to the backup computer must be performed manually, however. Equally important, all messages that originate at a node in the network travel in both directions around the NDC. Thus, a failure of one node by itself will not affect communications to the adjacent node since that same message will be received from the opposite direction around the loop. If the dedicated circuit between network nodes fails, an automatic backup capability via the direct distance dial (DDD) network is implemented. When the dedicated line quality improves, the DDD connection is dropped and service via the dedicated line is reinstituted.

If a site loses both of its computers, the alphanumeric terminal at the site automatically dials the NMC and functions as a remote terminal to the NMC until one of the computers is able to assume the load. In addition, communications to the two adjacent WSFO sites can be configured to bypass this site if necessary. This bypass operation is a manual function at present.

The NWS is currently involved in various stages of planning future programs that will have an effect on both the network and the local processing load for AFOS. One study calls for the inclusion of radar data onto the AFOS network. Another study is examining the effects of upgrading the AFOS network capabilities from 2,400 to 4,800 baud, and still another study is examining the possibility of transmitting image data via the AFOS network. Finally, a long-range goal of AFOS calls for the system to be used to generate local forecasts.

AFOS is a highly modular system and is thus capable of supporting increased processing and communication loads with minimal impact. Of the above studies, the capability to transmit image data stands to create the greatest impact on the system, possibly requiring the implementation of a satellite channel, operating in a broadcast mode.